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INVESTIGATIONS

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According to the general opinion we reckoned previously 3 species of Sandeel in Norwegian waters: *A. lancea* s. *tobianus* or the Lesser Sandeel, *A. cicerelus*[1]) or the Smooth Sandeel and *A. lanceolatus* or the Greater Sandeel.

They are mentioned both by COLLETT (7, 8, 9) and WOLLEBÆK (30) with so good characteristics that they are easily distinguished from each other. Yet the black spot on the side of the snout, mentioned by WOLLEBÆK (30 p. 216) in the Lesser Sandeel, is found in the greater but not in the Lesser Sandeel.

As to racial conditions of the Lesser Sandeel there has been great confusion up to recent days. What particulary caused the confusion was that different spawning periods and number of vertebrae were found not only in different waters, but also within the same area.

INVESTIGATIONS FROM FOREIGN COUNTRIES IN RECENT YEARS.

In 1910 GOTTBERG (19) mentions from Finnish Baltic waters the find of Lesser Sandeels, full of roe in autumn, and also occurences of newhatched larvae in spring. GOTTBERG (19) has no vertebral counts in his paper, but, based on the study of otoliths and measurements of young fish, he comes to the result that *A. lancea* at an average length of 40 mm is 1 year old, at 80 mm 2 years, at 110 mm 3 years and at 150 mm 4 years.

In 1934 RAITT (25) published a paper in which information is given of the find of a new species of the Lesser Sandeel in Scottish waters. He called it *Ammodytes marinus*. According to RAITT (25) it occurs in the North Sea and Northern Atlantic in greater number than any of the three other species. It is very much like *A. lancea* and therefore has so long escaped notice.

[1] RAFINESQUE named the species *A. cicerelus* in 1810. WOLLEBÆK, APPELLØF COLLETT, KRØYER, MORAU, SMITT, EHRENBAUM a. o. have the same spelling. Some authors spell: *Cicerellus*.

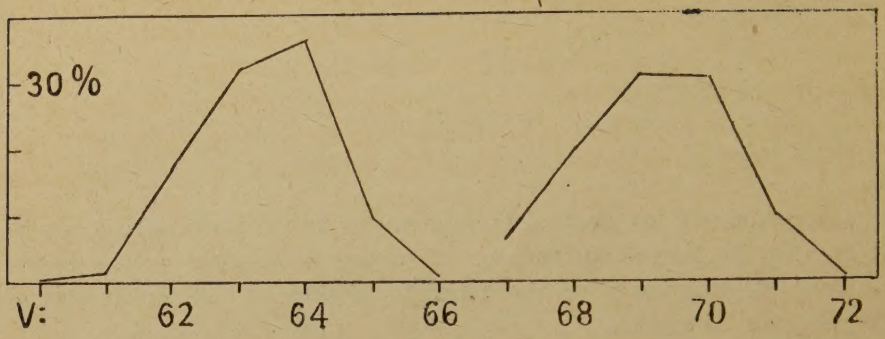

Fig. 1. Frequency distribution of vertebrae. Left *A. lancea*. Right *A. marinus*. (According to RAITT.)

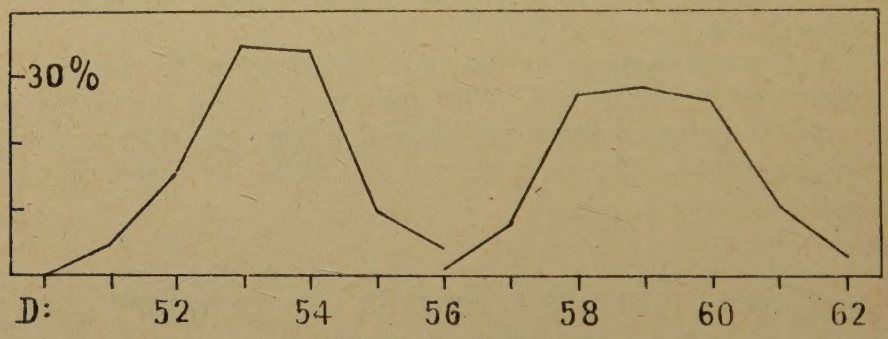

Fig. 2. Frequency distribution of dorsal rays. Left *A. lancea*. Right *A. marinus*. (According to RAITT)

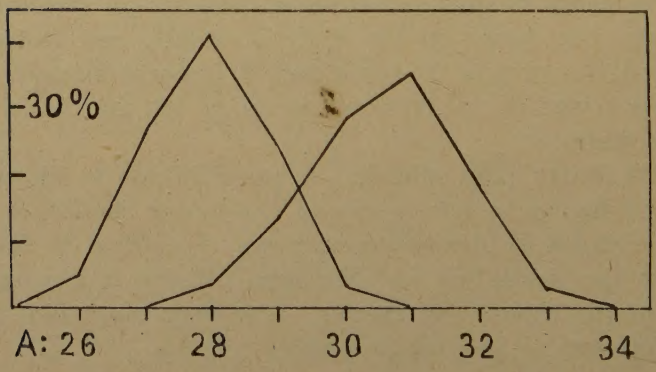

Fig 3. Frequency distribution of anal rays. Left *A. lancea*. Right *A. marinus*. (According to RAITT.)

There are, however, marked differences in the number of vertebrae and number of fin rays between the new species and the typical *A. lancea*. These deviations are so great that *A. marinus* must doubtless be regarded as a species of its own, provided that we acknowledge the view that the number of vertebrae and fin rays are hereditary factors, only to a small degree dependent on the influences of the surroundings. From RAITTS paper we here reprint the graphic description of the number of vertebrae (fig. 1), the number of rays in the dorsal fin (fig. 2) and anal fin (fig. 3) in the two species *A. lancea* (left on each fig.) and *A. marinus* (right on each fig.).

RAITT (25) maintained that the find of the new species solved the problem of the double spawning time of the Lesser Sandeel. The explanation, he says (p. 371), is that it is *A. marinus* which spawns in early spring, and *A. lancea* which spawns in summer. He continues (p. 372): »Sandeels never reach a size at which they are immune from attack, but at no time are they more heavily preyed upon than in the larval stage in which they appear in the north-western North-Sea in countless millions in the month of March year after year. This vital yearly influx of fish food, which has formerly been taken to belong to the species *A. tobianus*, is now seen to be the new form *A. marinus*. A complete revision of the European *Ammodytidae* is, therefore, a matter of deep necessity no less from a fishery point of view than from that of pure zoology«.

This publication excited general attention, and was the cause of new investigations of the Lesser Sandeel in a number of countries. The following year the German authors DUNCKER and MOHR (11) together published a revision of the species of *Ammodytes* in the collection of the Zoological Museum of Hamburg. They maintained that the greater part of the material which the museum had termed *A. tobianus*, ought to be reckoned to the new species *A. marinus*. The great majority of the material came from such northern tracts as Greenland and the White Sea. The lesser part only, which came from the coast of Germany appeared to be genuine *A. lancea* (s. *tobianus*). DUNCKER and MOHR (11) have no vertebral counts from the fish investigated. Investigations were made of the number of fin rays. But in addition to this they have used another characteristic in the Lesser Sandeel. In *A. lancea* as well as in *A. marinus* the scales are so small that they are scarcely discernible with the naked eye. Covering each row of scales there is a cutaneus fold, the rear end of which is free. These cutaneous folds (*plicae laterales*) were counted by DUNCKER and MOHR. The number of *plicae* is about double the number of vertebrae.

In 1939 the same authors published »Revision der Ammodytidae«

(12). Here *A. marinus* is combined with *A. dubius* from Greenland to make up one species *A. dubius* REINHARDT.

In 1935 BAHR (1) published a paper stating that *A. lancea* spawns both in spring and autumn. BAHR (1) also made estimates of age by means of scales and otoliths. His results — as will be mentioned later — have been critized by his fellow countryman KÄNDLER. BAHR (1) is of opinion that it scarcely can be justified to consider *A. marinus* as a species of its own.

In 1941 BRUUN (5) published investigations of the Lesser Sandeel from the Faroes and Iceland. He found that the material from both areas must be separated in two groups, one with a number of vertebrae of 60—66 consisting of spring spawners, and one with a number of vertebrae of 68—73, consisting of winter spawners. In the case of Iceland BRUUN says that the Lesser Sandeel seems to consist of two groups differing to some degree from the European species *A. lancea* and *A. marinus*. The number of vertebrae in one group from Iceland is considerably higher than in *A. marinus* from the North Sea. BRUUN finds this to be in accordance with the general rule that colder surroundings are connected with a higher number of vertebrae. In the second group the number of vertebrae is very low. BRUUN (5) also mentions that this may be caused by the fact that the animals in this group were caught in shallow lagoons along the south coast of Iceland. The material consists of 151 individuals from the Faroes and 149 from Iceland.

In a paper on Sandeel also published in 1941 JENSEN (20) has a chapter on nomenclature in which he states that the right thing should be to use the name *A. lancea* (CUVIER) instead of *A. tobianus* (LINNÉ). Among 83 individuals investigated, from 10 localities in Danish waters, JENSEN (20) found numbers of vertebrae from 60 to 65, and takes them all to be *A. lancea*. From Western Greenland waters he has a total of 217 individuals of the Lesser Sandeel from 19 different localities between 60½° and 72½° n. lat. In most cases the catches consist of a small number of individuals. Some are taken in the fjords, some in the open sea. The number of vertebrae in the material from Western Greenland falls into two groups. One, with the lowest number of vertebrae, is identified with *A. marinus*, and the other is taken as a particular subspecies, *A. lancea dubius*, with a number of vertebrae varying between 73 and 78. No mention is made of the spawning time of the Lesser Sandeel in Greenland waters. JENSEN (10 p. 29) takes the Lesser Sandeel for one single species: *Ammodytes lancea*, with 3 sub-species: *A. lancea lancea* CUVIER (V. 60—66), *A. lancea marinus* RAITT (V. 66—73) and *A. lancea dubius* REINHARDT (V. 73—78). The last one is known from Greenland waters only.

KÄNDLER (21, 22) has published several papers on the Lesser Sandeel. In 1941 he published a new paper (22) on the species of *Ammodytes* in the Baltic and German North Sea waters. This is his most important work. It is stated that *A. marinus* appears in both investigated waters, and that it spawns in the month of Desember. Moreover there is, in the Baltic as well as in the North Sea, one form of autumn spawners and one of spring spawners of *A. lancea*. The paper, based on a great material, contains photographs of otoliths and frequency distribution of number of vertebrae of the forms mentioned. We shall have to deal with this paper later.

INVESTIGATIONS IN NORWEGIAN WATERS.

Fin rays, number of vertebrae and spawning periods.

As far as we know no countings of fin rays and number of vertebrae have hitherto been made in material from Norwegian waters. In 1936 the material of Lesser Sandeels from »Bergens Museum« was at request placed at our disposal. As the material had to remain intact no vertebral counts could be made. The material consisted of 11 items. Each fish was measured. The rays in the dorsal and anal fins were counted. An investigation was also made of the number of *plicae laterales*. The fin rays sometimes were seen to be split, and often it was difficult to ascertain accurately the number of *plicae*. The reason was that on the anterior part of the investigated specimens there were spots where the *plicae* ran irregularly, only covering part of the side of the fish. New *plicae* also could develop down the side, giving a different number on the right and left side. The number of *plicae* therefore must be considered as a poor substitute for the number of vertebrae. When it is still used in the following pages, it is the average number of the two sides which is given.[2]

A revision of the material from »Bergens Museum« is rendered below. Here and in the sequel V. indicates the number of vertebrae. D. and A. numbers of rays in the dorsal and anal fin respectively and Pl. number of *plicae*. All samples in »Bergens Museum« are labelled *A. tobianus*.

Table 1. Bergens Museum 2093. Locality: Turø, Solsvik. August 3. 1911. This sample comprises 18 specimens. The three last ones were so decayed that the number of fin rays and *plicae* could not be fixed. In fig. 5 and 6 the number of fin rays in the dorsal and anal fins in the case of the first 15 fishes is shown by diagrams as in the previous figures. Even if the material of fish is small, a definite statement can be made to the effect that they are not in harmony with the corres-

[2] Where the averages are broken, the upper whole numbers are given.

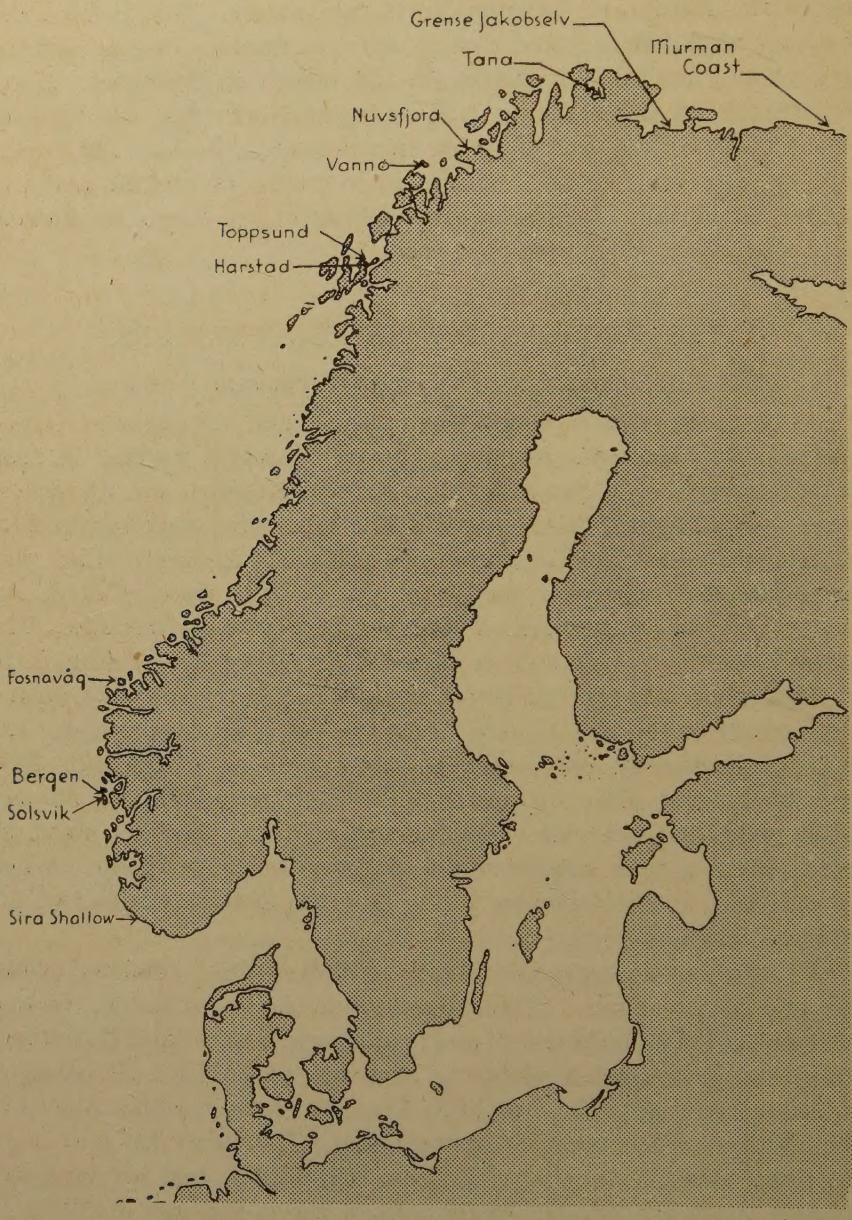

Fig. 4. Positions of samples from Norwegian waters.

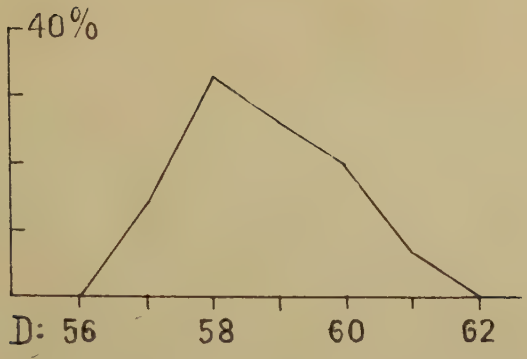

Fig. 5. Frequency distribution of dorsal rays. 15 ind. from Turö in the neighbourhood of Bergen, Norway.

ponding diagram of *A. lancea* in fig. 2 and 3. They agree well with RAITT's new species *A. marinus*.

Table 2. Bergens Museum 2007. Loc.: Søndagsholmen, Solsvik. 1899. Comprises only 2 fishes. The occurrence of such a high number of rays as 60 in the dorsal fin agrees with *A. marinus*.

Table 3. Bergens Museum 3714. Loc.: Nussfjord,[3] Finnmark. September 12. 1922. By comparing the numbers in the table with fig. 2 and 3 we see that *A. lancea* must be left out of the question. The numbers are remarkably high, even when compared with *A. marinus*. The animals have been caught in the far north.

Table 4. Bergens Museum 2903. Loc.: Skibotten, Lyngen, summer, 1915. The number of rays in the dorsal fins is even higher than in the preceding sample and far to the right of the *A. marinus* diagram in fig. 2. These fishes too have been caught in the far north.

Table 5. Bergens Museum 4041. Loc.: Djupedal, Herdla. August 28. 1925. Here the number of rays in the dorsal and anal fin corresponds well with *A. lancea*. It is also notable that the number of *plicae* in these fishes is lower than in the preceding samples.

Table 6. Bergens Museum 2005. Loc.: Solsvik, August 12. 1908. The number of rays in the dorsal and anal fins is in accordance with *A. marinus*.

Table 7. Bergens Museum 2994. Loc.: Turø, Solsvik. Undated. The number of fin rays and plicae is in accordance with *A. marinus*.

Table 8. Bergens Museum 2006. Loc.: Solsvik. September 20. 1909. One fish was damaged. The number of rays in the dorsal and anal fin is in accordance with *A. marinus*. The number of *plicae* indicates the same.

[3] Probably Nuvsfjord. Finnmark.

Mm.	D.	A.	Pl.
130	58	30	147
132	58	31	147
123	61	31	?
123	57	29	146
127	60	30	145
117	59	31	144
121	58	31	?
124	59	31	?
125	58	31	?
115	58	30	?
119	60	29	?
111	57	30	?
113	59	29	?
114	60	30	?
102	59	?	?
93	?	?	?
80	?	?	?
83	?	?	?

Table 1.

Mm.	D.	A.
76	57	31
62	60	31

Table 2.

Mm.	D.	A.	Pl.
117	62	32	151
134	62	33	153
121	58	32	145

Table 3.

Mm.	D.	A.	Pl.
108	62	33	?
96	63	32	?
84	63	32	?

Table 4.

Mm.	D.	A.	Pl.
80	54	29	131
79	52	28	126
77	51	28	128
74	53	28	130

Table 5.

Mm.	D.	A.	Pl.
96	59	30	?
99	58	30	?
71	58	30	?

Table 6.

Mm.	D.	A.	Pl.
132	59	30	139
132	59	31	141

Table 7.

Mm.	D.	A.	Pl.
102	57	29	146
97	?	31	?
97	60	31	144

Table 8.

Mm.	D.	A.	Pl.
114	61	32	147
132	64	34	151
117	62	32	148

Table 9.

Mm.	D.	A.	Pl.
68	?	?	?
109	61	31	151
108	59	31	143

Table 10.

Mm.	D.	A.	Pl.
164	62	32	145
178	62	33	153
144	60	32	147
119	62	32	148
117	61	33	148

Mm.	D.	A.	Pl.
123	61	32	151
111	60	30	148
135	61	32	147
119	62	31	148
114	61	32	150

Table 11.

Mm.	D.	A.	Pl. l.	Pl. r.	V.	♂ ♀	Stage
167	62	32	154	146	72	♀	V
132	60	31	146	149	71	♀	V
144	59	32	145	145	69	♂	V
145	61	32	145	152	73	♂	IV
118	60	31	143	145	70	♂	V
139	60	32	150	150	71	♂	IV
115	63	34	150	151	74	♀	II
124	61	31	149	148	72	♂	V
130	63	32	171	180	73	♂	V
122	61	31	154	155	71	♂	V

Table 12.

Stage	I	II	III	IV	V	VI	VII
Number	0	1	0	4	84	0	0

Table 13.

Stage	I	II	III	IV	V	VI	VII
Number	0	46	132	22	0	0	0

Table 14.

Stage	I—II	III	IV	V	VI	VII	VIII
Number	12	0	0	39	135	3	1

Table 15.

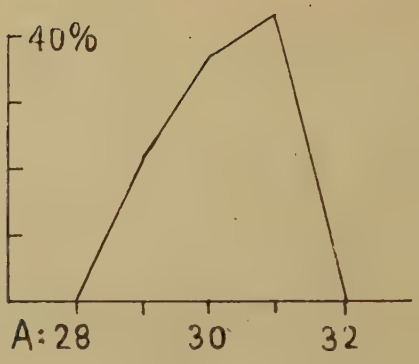

Fig. 6. Frequency distribution of anal rays. 15 ind. from Turö.

Table 9. Bergens Museum 3727. Loc.: Arnø,[4] Lofoten. 1922. This cannot possibly be *A. lancea*. The number of fin rays is almost beyond the limit of the diagram of *A. marinus* in fig. 2 and 3.

Table 10. Bergens Museum 3715. Loc.: Vannø, Lofoten. August 5. 1922. Here we make the same statement as in the case of the preceding sample.

Table 11. Bergens Museum 2148. Loc.: The Murman Coast. June 27. 1908. Here the same statement can be made as in the case of the other samples from the far north. The most interesting thing was that some of the fishes had been opened, thus making it clear that the gonads were in a state to show that the fishes had not spawned in the year when they were caught, but that they would probably have spawned that year if they had lived longer.

As a summary of the material from »Bergens Museum« it can be stated that the individuals in all samples have a number of rays in the dorsal and anal fin as high as in *A. marinus* except 4041 from Djupedal, Herdla. The countings in the animals of this sample are in accordance with what is generally found in *A. lancea*. But in the individuals from the northernmost waters, the numbers of fin rays both in the dorsal and anal fins are almost beyond the upper limit fixed by RAITT (25) for *A. marinus*. The fishes from the Murman Coast show another spawning period than that found by RAITT (25) in his new species.

During the cruise of M/C »Johan Hjort« to Northern Norway in 1938 some samples of the Lesser Sandeel were secured. We shall have to deal with one of these. It was taken at Elgsnes in the Toppsund on September 25. In the table 12 Pl. r. indicates the number of *plicae* on the right side of the fish, Pl. l. the same on the left side. The deve-

[4] Probably Arnø by Harstad.

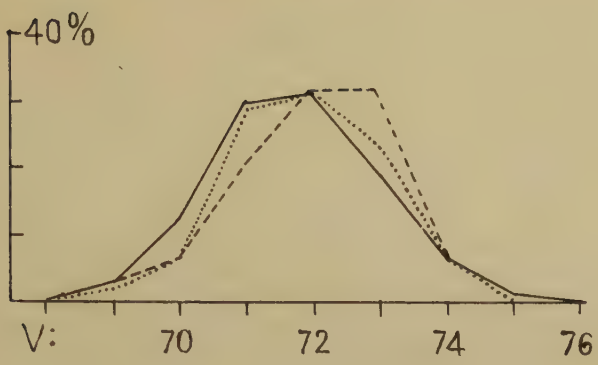

Fig. 7. Frequency distribution of vertebrae.
..... 89 ind. from Lavonjarg, Tana, Finnmark, Norway.
——— 200 ind. from Grense Jakobselv, Finnmark, Norway.
– – – – – – 170 ind. from Grense Jakobselv, Finnmark, Norway.

lopment of the gonads is indicated by Roman numerals from I to VII according to Heincke's scale which has been worked out for herring, but is available also in the case of Sandeel. Accordingly I means young fish with quite undeveloped gonads and VII spent fish with only remnants of sperm or single eggs left. This sample (table 12) shows the same as the material from »Bergens Museum«: The number of vertebrae as well as the number of fin rays is highest in the Lesser Sandeels from the far north. This is also the case with the number of *plicae*. We also see how the number of *plicae* varies from the left to the right side of the fish. Moreover the sample shows evidently that these Lesser Sandeels are autumn spawners.

In all samples hitherto mentioned the number of fish has been small. To obtain a reliable frequency distribution of the number of vertebrae or the number of fin rays, as in fig. 1, 2, and 3, samples numbering between 100 and 200 fishes are necessary where the dispersion is so great.

On the September 16, 1939, a sample of the Lesser Sandeel was taken at Lavonjarg, Tana, Finnmark. The diagram of the number of vertebrae is given in fig. 7 (dotted). There were 47 males and 42 females in the sample. The gonads showed the development given in table 13.

The sample was conserved in a 3 % solution of formaldehyde immediately after the capture. In a letter accompanying the sample the sender gives the information that the Lesser Sandeel occurs in countless numbers at the mouth of the Tana river and some distance up the river. It spawns in the mouth of the river and outside on the great sandbanks. The spawning is said to take place in the months

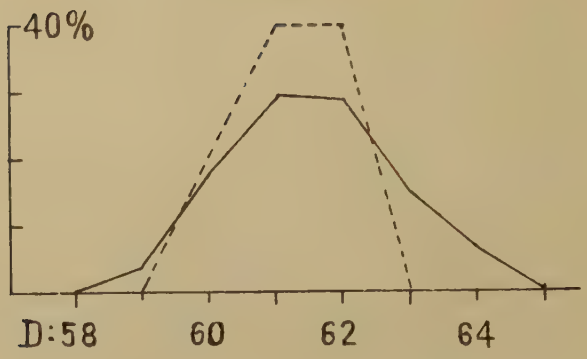

Fig. 8. Frequency distribution of dorsal rays.
———— 200 ind. from Grense Jakobselv, Finnmark, Norway.
- - - - - - 10 ind. from the Murman Coast, Russia.

of November and December. The young fish is observed for the first time in the end of May, then being about 25 mm long.

Another sample was taken on July 17 at Grense Jakobselv, Finnmark. It comprised 200 specimens, which were also conserved in a 3% solution of formaldehyde immediately after the capture. Fig. 7 shows the diagram of the number of vertebrae (unbroken line) in this sample. Fig. 8 shows (unbroken line) the diagram of the number of rays in the dorsal fin and fig. 9 (unbroken line) in the anal fin in this sample. In fig. 8 and 9 the corresponding diagrams (broken lines) have been drawn for the sample »Bergens Museum 2148« from the Murman Coast. As above mentioned this comprised 10 fish only. But the figures show that these diagrams harmonize with the corresponding ones for the great sample from Grense Jakobselv.

As to one part of the fish from the Murman Coast it has been mentioned previously that the development of gonads indicated their being autumn spawners. This is confirmed by the sample from Grense Jakobselv. The development of gonads in this sample is given in table 14. There was about the same number of males and females in the sample.

In the same year a new sample from Grense Jakobselv was taken on October 30. It was also conserved in a 3 % solution of formaldehyde immidiately after the catch. Fig. 7 shows the diagram (broken line) of the number of vertebrae in this sample. It comprised 170 individuals, 78 being males and 92 females. The gonads showed the development given in table 15. One female fish showed a farther regeneration of the ovaries than the remaining spent female fishes. Some half resorbed remaining eggs showed that also this fish had spawned not long ago.

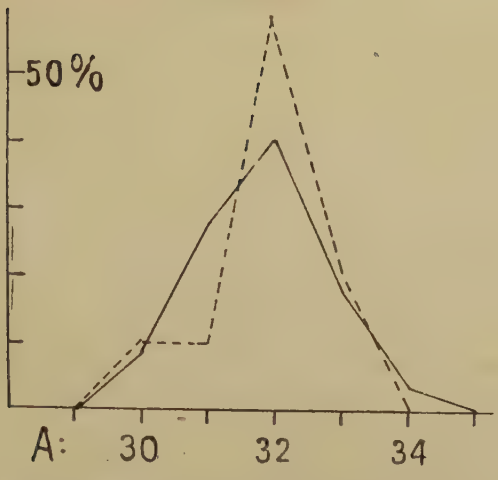

Fig. 9. Frequency distribution of anal rays.
——— 200 ind. from Grense Jakobselv, Finnmark, Norway.
- - - - - - 10 ind. from the Murman Coast, Russia.

But the ovaries approached the stage indicated as II. This fish has been recorded in stage VIII.

The sender of the sample gives the information that the Lesser Sandeel at that locality is thought to be spent in October, the young fish being observed for the first time in the month of July, then having a length of 50—70 mm.

A sample consisting of more than 200 Lesser Sandeels was taken at Sandvika in Bergen harbour on September 2, 1941. Fig. 10 shows the frequency distribution of vertebrae in this sample (unbroken line). As will be seen the curve falls within the limits of the curve corresponding to *A. marinus* in fig. 1. As this sample comprised only immature individuals, barely exceeding 100 mm in length, the gonads can give no elucidation of the spawning time.

In 1944 a sample of Lesser Sandeels was collected from the stomachs of fish caught in Danish seine at Fosnavåg, Sunnmøre on June 27. The sample, comprising 340 individuals, was easily separable in 2 size groups, one group numbering 20 individuals with lengths from 117 to 133 mm, the other numbering 320 with lengths from 62 to 80 mm. The length distribution for this group was symmetrical about a mode at 70 mm.

The whole sample was stained with alizarine. After this the vertebral numbers were easily counted by means of a binocular lens. The frequency distribution of vertebrae for 200 animals of the greater group is given in fig. 10 (broken line). It has a mode at 71. In other words the number of vertebrae lies higher than in *A. marinus*.

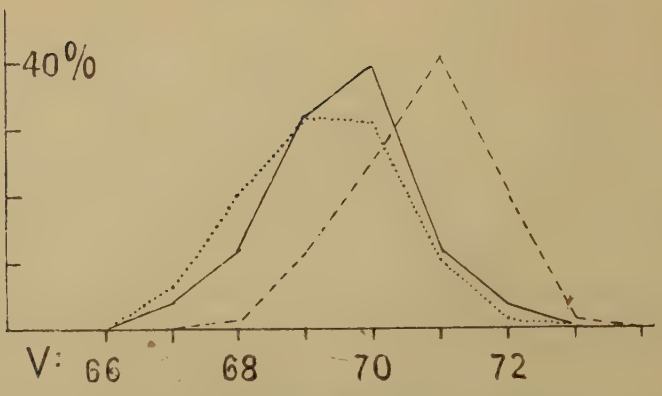

Fig. 10. Frequency distribution of vertebrae.
– – – – – – 200 ind. from Fosnavåg, Sunnmöre, Norway.
———— 200 ind. from the harbour of Bergen, Norway.
..... *A. marinus.* (According to RAITT.)

The frequency distribution of vertebrae in the Lesser Sandeel from Norwegian waters has modes at 70 (Bergen), 71 (Fosnavåg), 72 (Tana) and 72—73 (Grense Jakobselv). That is to say a gradual increase in the vertebral number north- and eastward. It has also been ascertained that the Lesser Sandeel spawns in late autumn in Finnmark.

On February 24, 1937 a little tuft of algae was taken with Petersen's bottom sampler from a depth of 37 m on the Sira Shallow. These algae were bearing 12 eggs of Lesser Sandeel. The development of the eggs indicated that about half of the hatching time had passed. Pigment had only just begun to develop in the eyes of some of them. According to KÄNDLER (22) the hatching period of the Lesser Sandeel is about 10 days at a temperature of 14°—15° Celsius. The temperature-conditions on the Sira-Shallow the said winter (EGGVIN 13 and 14) give every reason to believe that these eggs would only have been hatched in early spring and that they must have been spawned rather a long time ago.

Age Estimates and Growth Measurements.

COLLETT writes (8 p. 94) as follows: »*A. tobianus* I found in the end of July 1880 to appear at Grøtø in Lofoten in 3 age groups simultaneously between which there were at that time no transition forms. These groups had a total length of 75, 125 and 170 mm and were probably 2, 3 and 4 years old«. It is not mentioned how great the material is on which these measurements are based. GOTTBERG (19, p. 30) later found his own results to be in accordance with this.

Age estimates based on length measurements only, will easily cause some uncertainty. This is particularly the case in the Lesser Sandeel which has been found to have both a far extended spawning and hatching period. KÄNDLER (22, p. 104) says about the catches of *A. marinus* in the Baltic: »»Sonderbar ist dass ihre mittlere Länge mit fortschreitender Jahreszeit nicht zunahm, sie ging vielmehr etwas zurück, von 12,3 cm in Juli auf 11,7 cm in Oktober«. Under such conditions length measurements alone will be precarious as a means of age-estimation. This will also be the case even when otoliths or scales are used if we do not take into consideration the fact that spring spawners as well as autumn spawners may coexist in the same waters and if we are unable to distinguish between the otoliths of them. Therefore BAHR'S (1) age investigations will, as shown by KÄNDLER (22, p. 102), for this reason be only approximately correct.

The sample from Fosnavåg above mentioned, comprised two size groups. The sample was taken on June 27. It was natural to take the small individuals for the young fish of the year. A closer investigation of the otoliths indicated that this was really the case. The otoliths had a size of very nearly 1 mm, and, after being dehydrated in alcohol and transferred to xylol showed only one single opaque layer. Three of these otoliths are shown on photograph A in the appended plate.

The otoliths from the larger specimens in the sample were on an average 2,4 mm long. With the naked eye it could be seen that they consisted of an inner opaque nucleus surrounded by a glassy outer layer. After being transferred to xylol this structure could be distinctly seen. The photograph A also shows one of these otoliths. The whitish nucleus indicates the summer zone and the vitreous outer layer the winter zone.

This photograph also will serve to show that the otoliths in both cases seem to come from individuals hatched in spring. The otolith is present in the newly hatched larva. Larvae hatched in early spring will have otoliths with a large opaque nucleus representing a whole summer's growth, while the otoliths in autumn — hatched larvae will be characterised by a small opaque nucleus. (KÄNDLER 22). Similar conditions are known from the scales and otoliths from other fishes. The otoliths, however, have, as mentioned by KÄNDLER, the advantage of delineating the whole life of the fish, while the scales do not show the time from the hatching until the scales develop during the metamorphosis.

Fig. 11 shows — from KÄNDLER's fig. 15 — growth zones in otoliths from *A. marinus* (a), *A. lancea* spring spawner (b) and *A. lancea* autumn spawners (d). That the large group of more than 200 animals in the sample from Fosnavåg was hatched in spring the same year seems to

be proved by the fact that the otoliths had no winter ring at all. But the great opaque nucleus in all otoliths in the lesser group indicates that also this lesser group consisting of greater individuals had been hatched in spring. A number of the otoliths from these group also showed a new, barely commenced summer zone.

The otoliths from the sample from Sandvika in Bergen were unfit for use owing to the action of acid formaldehyde. But there were scales on all animals in the sample. None of these scales showed more than one single growth zone. The individuals in the sample measured from 96 to 115 mm. The length distribution was apparently normal with a mode at 105 mm. Even if the scales on the younger individuals of the Lesser Sandeel are not so well suited for an age estimation as the otoliths, a winter ring on the scales of these young animals could not well escape notice. Therefore it may be considered as a fairly safe inference that these were animals hatched the same year.

It might be objected that larvae hatched in autumn would stagnate in their development during the first winter, so that this period of their lives would not be delineated in the scales, thus making it possible for the animals in the sample from Sandvika still to have been hatched in the previous autumn.

No otoliths, however, harmonizing with KÄNDLER's description of otoliths from autumn spawning Sandeels, have occured in any sample from Norwegian waters. In all the samples the otoliths investigated had the opaque nucleus characteristic of individuals hatched in spring, as shown by fig. 11, a and b. Even the otoliths from the above mentioned sample from Grense Jakobselv, taken on October 30, show this characteristic appearance. This seems to indicate that the eggs in Northern Norway remain unhatched through the winter, on account of the cold water, are hatched only in early spring. This also harmonizes with the above mentioned find of eggs of the Lesser Sandeel on the Sira Shallow.

This does not exclude the possibility that there do exist spring spawning Lesser Sandeels in Norwegian waters. If so, we shall expect them to be found in shallow water. The above mentioned find of 4 individuals from Herdla (Bergens Museum 4041) which all of them had a remarkably low number of fin rays, may have been spring spawners. The otoliths were damaged and unfit for use. But the sample is said to have been taken in shallow water.

Photograph B shows the otolith of a specimen, 138 mm long, from Grense Jakobselv. It contained roe at stage III—IV, and was caught on July 17, 1939. We see the great, whitish nucleus, 1 winter ring and a new summer zone. The otolith has been ground down to the centre.

Photograph C shows the otolith of a specimen, 167 mm long, caught at Elgsnes in the Toppsund on September 25, 1938. It contained roe at stage VI. We see the big nucleus characteristic of fish hatched in spring, and several winter rings. The ~~third~~ 4th summer zone has the appearance which in otoliths from other fishes (cod, haddock) has proved to be characteristic of the year when the individuals attain maturity. Subsequent summer zones are narrower and less distinct, corresponding to the decreasing growth of the fish after the first spawning year. The otolith was treated as in the case of B.

SPECIES AND RACES IN THE LESSER SANDEEL.

As early as in 1838 REINHARDT had established a particular species of Lesser Sandeel from Greenland on account of the high number of fin rays which he found in the material from there. As material from different areas gradually was investigated, it has become apparent that the number of vertebrae and fin rays was nowhere strictly speaking the same. We have seen that if we compare the investigations made by various authors it is obvious that the vertebral number (and number of fin rays) — taken as a whole — increase the farther to the north the investigated areas lie. In addition to this a number of authors in recent years have found two groups in the vertebral number within the areas investigated. The group with the lowest vertebral number is called *A. lancea*, the other being identified with *A. marinus*. There is a general agreement that *A. lancea* is a coastal form living in shallow water, and that *A. marinus* lives in deeper water, and chiefly in the open sea. *A. lancea* is found to spawn in spring (as shown by BAHR (1) and KÄNDLER (20,21) also in autumn), and *A. marinus* chiefly in winter or early spring. JENSEN (10 p. 30) says about this: »As regards the vertical distribution there is thus on the whole distinct difference between *A. lancea* and *A. marinus*, the former being found in fjords and near the coasts in shallow water, while the latter occurs away from the coasts in deeper water«. As regards the distribution of *A. marinus* and *A. dubius* in Greenland waters he says (20, p. 21): »It can further be noted, as seen from the lists, that while *A. marinus* hitherto has been taken in fjords and near the coasts only, *A. dubius*, besides on the coast, was found several times in Davis Strait. However, it may be stated that the present collection is not sufficient to determine the distribution in detail«.

The two quotations do not seem to agree very well, but as nothing is mentioned of the spawning conditions of the Lesser Sandeel in Greenland waters it may be possible that here we have also to do with spring

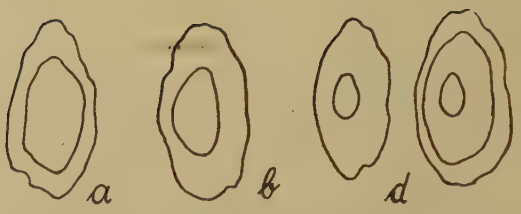

Fig. 11. Zones of growth in otoliths from Lesser Sandeels. a. *A. marinus*. b. *A. lancea* spring spawner. d. *A. lancea* autumn spawners. (According to KÄNDLER.)

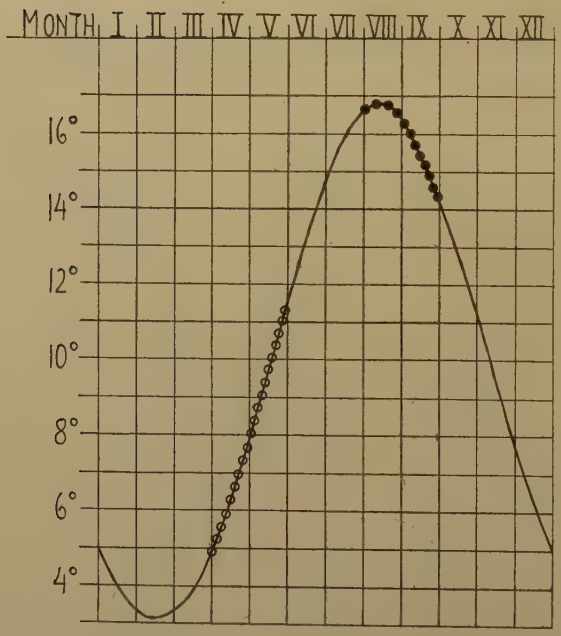

Fig. 12. Temperature during the year in the surface at Helgoland.
○○○○○○○○ spawning of *A. lancea* in spring.
●●●●●●● spawning of *A. lancea* in autumn.

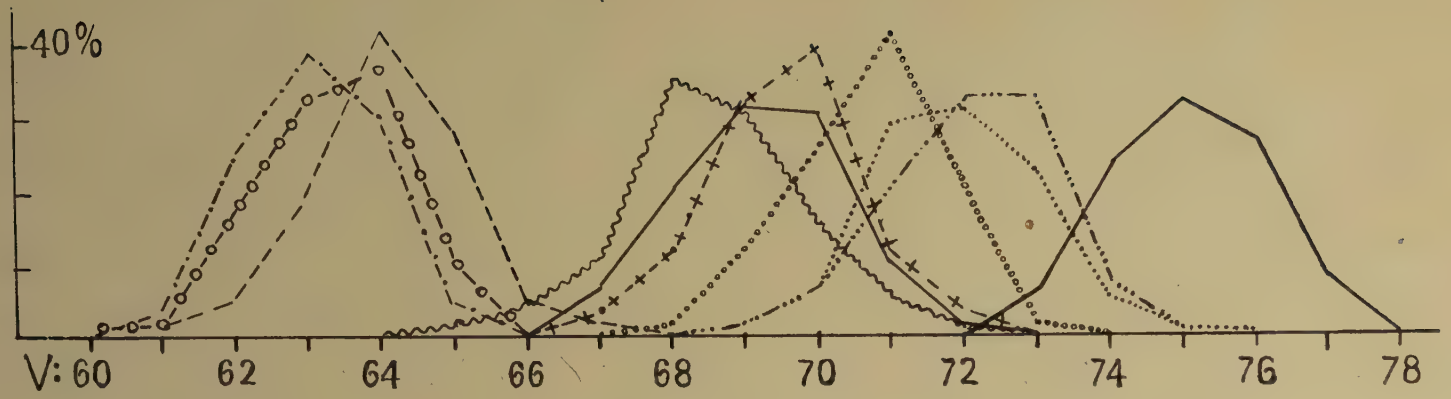

Fig. 13. Frequency distribution of vertebrae.

.-.-.-.- *A. lancea*, spring spawner. North Sea. (According to KÄNDLER.)

-o-o-o- *A. lancea*, (According to RAITT.)

- - - - - - *A. lancea*, autumn spawner. North Sea. (According to KÄNDLER.)

~~~~~~~ *A. marinus*. Baltic. (According to KÄNDLER.)

——— *A. marinus*. (According to RAITT.)

-+-+-+-+ Lesser Sandeels from Bergen harbour, Norway.

-.-.-.-.- Lesser Sandeels from Grense Jakobselv, Finnmark, Norway.

..... Lesser Sandeels from Lavonjarg, Tana, Finnmark, Norway.

°°°°°°°°° Lesser Sandeels from Fosnavåg, Sunnmøre, Norway.

——— *A. dubius*. Greenland. (According to JENSEN.)
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spawners in shallow water with a relatively low vertebral number and autumn- or winterspawners from the open sea with a relatively high vertebral number. Only that this number in both cases is so much higher than what is found in other areas.

KÄNDLER (22) has shown that in the Baltic as well as in the North Sea there is one form of spring spawners and one of autumn spawners of *A. lancea*, both living in shallow water and both having approximately the same number of vertebrae. He says about this (21, p. 134): »Diese doppelte Laichzeit findet ihre Erklärung im Vorhandensein zweier Saisonrassen«.

In this connection it is worth while mentioning that in the Baltic as well as in the German Bay the sea-water has the same temperature twice a year (with exception of the middle of August and the middle of February). Fig. 12 shows a curve of temperature for the monthly mean values at 0 m at Helgoland. It has been drawn in accordance with statements given in 6, in the list of literature. On the curve the spawning period according to KÄNDLER (22) in spring has been marked with open circles, and in autumn with filled up circles. The fig. seems to show that a greater part of the larvae in the first part of their lives after the hatching will grow up in such water where the temperature is the same in both cases.

All these things seem to indicate that the temperature in the sea during the first part of the lives of the Lesser Sandeels after they have been hatched, has a decisive influence on the number of vertebrae (and fin rays) in the larvae. Fig. 13 shows a comparison between some of the curves of frequency distribution of vertebrae above mentioned. To the right is seen the curve of *A. dubius*, drawn according to the table of JENSEN (20, p. 19). The whole material of *A. dubius* from Western Greenland (179 specimens) has been considered as one sample.

It will be seen that the samples from Norwegian waters fill up the gap between the curves of *A. marinus* from the Baltic and *A. dubius* from Western Greenland. Between the curves of *A. lancea* autumn spawner from the North Sea and *A. marinus* from the Baltic there is a gap. Lesser Sandeels with a number of vertebrae to fill up this — i. e. between 64 and 68 — are not yet known. But it would be interesting to search for them in localities where the larvae after hatching will grow up in water of temperatures between what is the case with the larvae of *A. marinus* from the Baltic and the larvae of *A. lancea* autumn spawner from the North Sea.

This does not imply that we needs must search for the mature individuals in such localities. We must take into account that the larvae in their pelagic stage, may be carried rather far away.

ORIGIN AND IMPORTANCE OF THE NORWEGIAN STOCK OF THE LESSER SANDEEL.

In the introduction RAITT's reference to the Lesser Sandeel as food for other fishes has been mentioned. From KÄNDLER's fig. 13 we here reprint in fig. 14 a chart of the occurence of larvae of *A. marinus* in the German Bay in February—March 1904—1908. It will be seen that the great majority of the larvae has been caught at a depth between 20 and 40 m, and that the number of larvae occurring per square meter of surface is here so great that only the spawning grounds of the Spring Herring can show a similar density of fish larvae.

The remarkable fact observed in this map is that the area showing the greatest number of larvae is practically identical with the spawning ground of the Sprat in these waters. It is a general supposition that the shoals of young Sprat occurring along the coast of Norway are recruited from this and other southern spawning areas. According to SUND (28) the pelagic Sprat eggs and the young fish are carried to the north along with the coastal current and grow up in Norwegian waters. Recent investigations by BJERKAN (2, 3) have shown that the Sprat fishery in Norway depends upon the nature of this transport both with regard to quantity and to quality of the catches.

There are reasons to believe that the young fish of the Lesser Sandeel too are carried northward by the same currents, and consequently that a greater or lesser part of our stock of the Lesser Sandeel in Southern Norway is of southern origin. Fig. 15 shows a chart of currents of the surface water in the North Sea, according to TAIT (28). As will be seen a particle of water or a planktonic organism in the German Bay may be carried towards the Norwegian West coast the more direct way right across the mouth of Skager Rack. It also may bend round the Skaw towards the western coast of Sweden before it is carried towards the Norwegian coast.

According to a computation of Dr. EGGVIN a particle of water will take about 50—55 days from the German Bay (off Sylt) to the Sognesjøen on the Norwegian coast by following the shortest route and about 75—80 days by the longest route. As February and March are the months in which the greatest number of *A. marinus* eggs are hatched, the first important transport of young fish from there will arrive at the Sognesjøen in April by following the shortest route and in May—June by following the longest of the transport routes above mentioned.

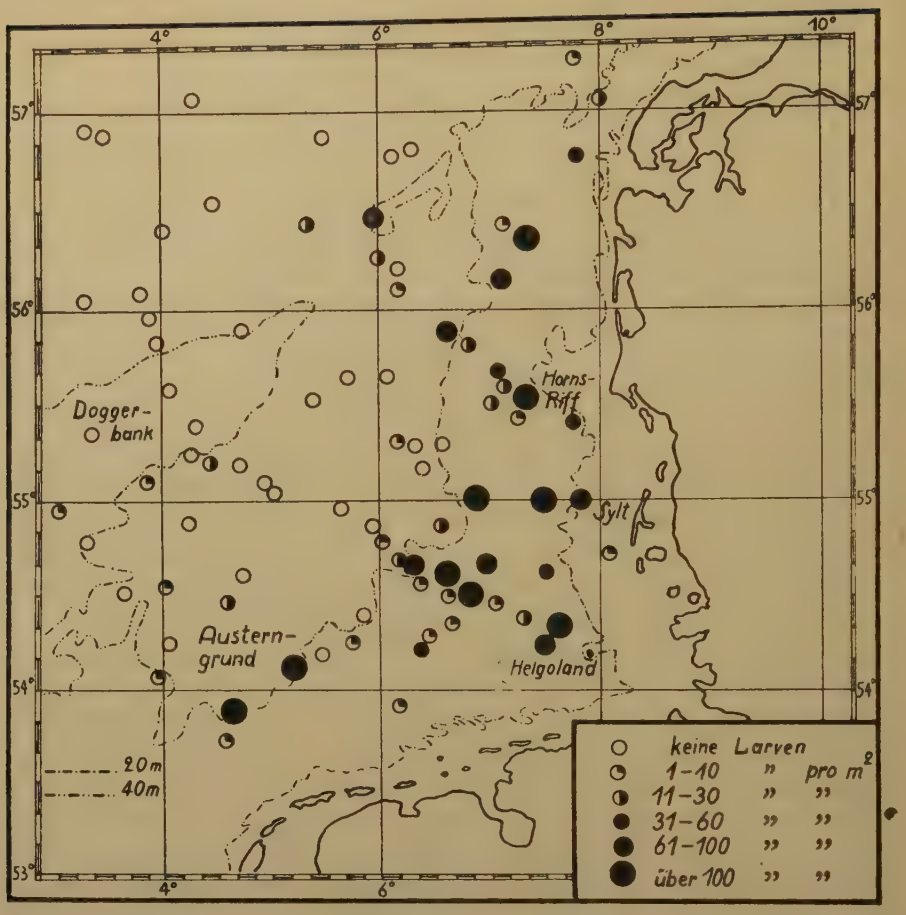

Fig. 14. The spawning ground of *A. marinus*. (According to KÄNDLER.)

It will be of great importance to start a closer investigation of this northward drift of the young fish. As above mentioned the Lesser Sandeel serves as food for other fish, at the mature as well as the immature stage. Many years ago BJERKAN has shown that the mature Lesser Sandeel made up perhaps the most important part of the food for the Plaice which are taken in Danish seine in summer time on the coast of Norway.

It is generally known that Sandeels are excellent bait. Particulary in former days people used to catch them for this purpose in shallow bays in nets with fine meshes. In Northern Norway where the difference between ebb and flow is particularly great, the Lesser Sandeel has been dug up from the sand at ebb time. In former days Sandeel for bait was an article of commerce in Northern Norway.

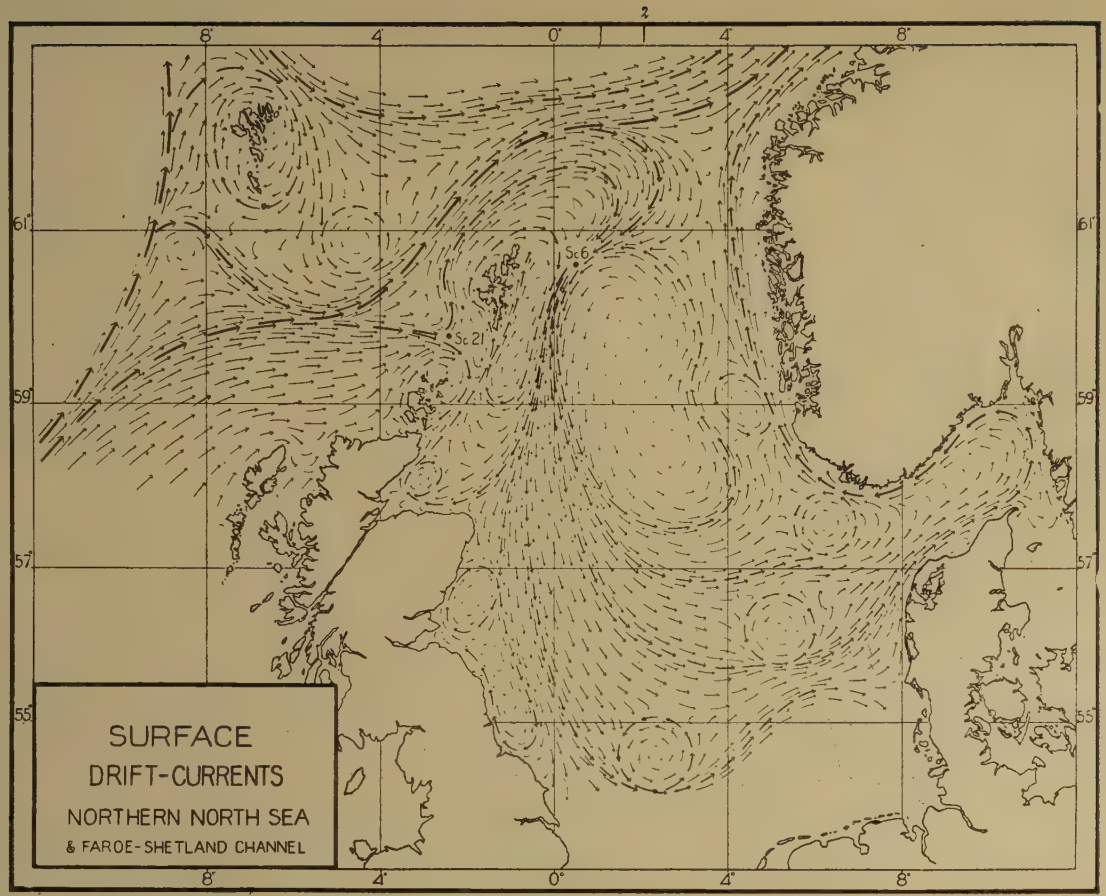

Fig. 15. Currents in the surface layers in the North Sea. (According to TAIT.)

People along the Norwegian coast knew the Lesser Sandeel to occur in the summer months in pelagic shoals. On such occasions parts of the shoal happened to be caught in purse seine because the fishermen falsely took it to be Sprat or young Mackerel. The fishermen also knew the Lesser Sandeel to occur in shallow water, particulary where the bottom consisted of sand, and knew it to bury itself in the sand when it was frightened or wanted to rest. But beyond that fishermen knew very little about the life of the Lesser Sandeel. The development of the Danish-seine fishery in Norway in recent years has partly caused an alteration in this.

It has proved to be a matter of fact that when the Lesser Sandeel is present the fishery with Danish seine will give good results, while the catches of gear with bait will decrease. On the contrary will the catches of gear with bait increase when the Sandeels are absent. This has caused fishermen who formerly worked with Danish seine this year (1944) to change to long-lines, giving the absence of Sandeels on the fishing grounds as reason. The fishery with Danish seine in Southern Norway has further proved that the stock of Lesser Sandeels on the fishing grounds here is highly variable, not only from season to season, but also from one year to the other. It is natural to take the above mentioned transport of young fish from southern waters as an explanation. But proofs have not yet been given.

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PLATE.

EXPLANATION.

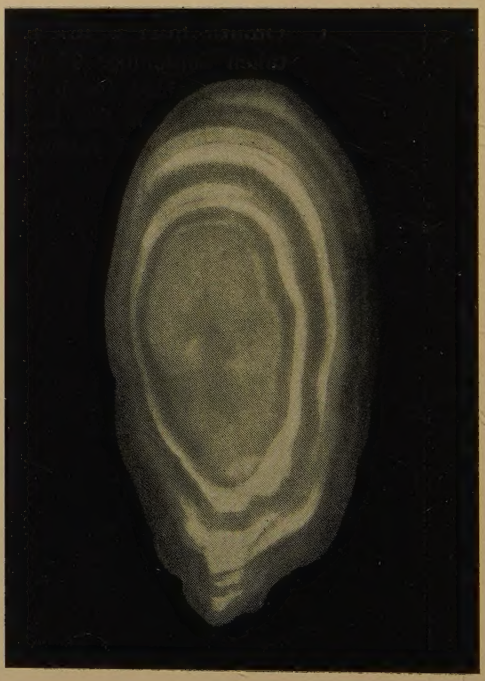
A. Otoliths from Lesser Sandeels taken June 27 by Fosnavåg, Sunnmöre, Norway. 3 otoliths from the 0 group. 1 from the 1 group.

B. Otolith from a 138 mm Lesser Sandeel. It was taken July 17 by Grense Jakobselv, Norway, and belongs to the 1 group. The large nucleus indicates that the fish is hatched in spring.

C. Otolith from a 167 mm Lesser Sandeel. It was taken September 25 by Elgsnes, Lofoten, Norway, and contained roe in stage VI. The large nucleus indicates that the fish is hatched in spring. It seems to have matured in the ~~third~~ 4th summer of its life.

A (× 20).

B (× 32).



C (× 26).